Level II BASIC On a Z-80 System

Although the author used Radio Shack's three-ROM BASIC, the two-ROM version should work as well.

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Since I have been a dedicated hardware hacker for many years, I just had to build my own computer. I started designing at Christmas in 1976. By September 1977 I had my computer basically working, and by Christmas 1977 It was working In BASIC. It was a 2K Tiny BASIC interpreter, but it was better than nothing.

After about a year of using my Tiny BASIC, I decided I was ready for a real BASIC. Since I had chosen the Z-80 microprocessor for my computer, I could use any BASIC written for the 8080 or the Z-80.

There were a number of BASICs available that required from 8K to 24K of memory at prices from $50 to several hundred dollars. I really liked the idea of having the BASIC in ROM so that I wouldn't have to load It from tape every time, which seemed to take forever. (Even with my 2400 baud cassette interface, programs longer than 4K become annoying!) This meant I had to either use EPROMs or buy the BASIC already in ROM. The EPROMs would cost upwards of $80, plus the price of the BASIC.

There was only one BASIC offered in ROM that I knew of, although I had heard rumors of another one coming soon. The rumors have since become fact, and Livermore BASIC is now available on an 8K byte ROM for $95. I bought the other one, Radio Shack's Level II BASIC, for $89.10. (Several companies offer ten percent off Radio Shack's original $99 price. Radio Shack has since raised the price to $120.)

Radio Shack's Level II BASIC has another significant advantage—software availability. Since it is the most popular microcomputer around today, It has much software designed for it. Also, many programs not originally written for it are being offered in compatible forms (for example, the CP/M disk operating system and the Electric Pencil).

In this article, I will describe how I interfaced the Level II ROMs to my computer, even though my hardware bears little resemblance to that of the TRS-80. I will also give some hints to those computerists whose hardware doesn't resemble mine either!

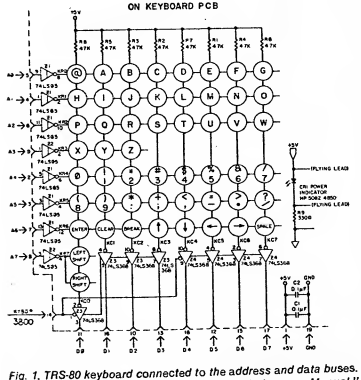


Fig. 1. TRS-80 keyboard connected to the address and data buses. (Reprinted from the "TRS-80 Technical Reference Manual," courtesy Radio Shack.)

Before I bought the Level II ROMs, I did some preliminary investigation, which included rereading articles that described the TRS-80 hardware and software. I also bought and read the "TRS-80 Microcomputer Technical Reference Handbook" published by Radio Shack. All of this material provided several important pieces of information.

First, the TVT was a more or less standard type of memory-mapped interface, which, I figured, should present no problems.

Second, the keyboard was an unorthodox arrangement with the key matrix directly mapped in memory (see Fig. 1). I figured I could write a program to take ASCII data from my keyboard and calculate the required memory bits to set so that the ROM could find the bits in memory and convert them back to ASCII (a kludge, but it worked!).

Third, the cassette interface was software timed and would require a different clock rate on my processor or else some software patches to get the timing right.

Finally, and perhaps most importantly, the ROMs were located in memory at address 0000H. This meant I would have to move my monitor, which was now there, to another address. I moved it to F000H. This required a reset vector other than 0000H to initialize to the monitor.

The circuit I used was described in the September 1977 *Kilobaud* ("Using an Invisible PROM," p. 106, by Jack Regula). My version Is in Fig. 2. I spent the next month or so rewriting and improving my monitor. When I had it just right, I put it in

Preliminary Work

```
00100 ;TRS-80 KEYBOARD SYMULATOR INTERRUPT ROUTINE
00110 ;BY RICHARD J. USCHOLD
00120          ORG 0F776H
00130 TKEINT   PUSH HL        ;SAVE REGISTERS
00140          PUSH AF
00150          PUSH BC
00160          LD A,3CH       ;MASK KEBD AND LOWER INTS
00170          OUT (INTMSK),A ;FOR MY SYSTEM ONLY
00180          EI
00190          XOR A          ;CLEAR A
00200          LD B,8         ;LOOP COUNT
00210          LD HL,3801H    ;KEBD MEMORY ADDRESS
00220 CLRLOP   LD (HL),A      ;CLEAR KEBD ADDRESS
00230          RLC L          ;GENERATE NEXT ADDRESS
00240          DJNZ CLRLOP
00250          LD L,0FFH      ;KEY PRESSED BYTE
00260          LD (HL),A      ;CLEAR IT
00270          IN A,(KEBD)    ;GET DATA FROM KEYBOARD
00280          LD C,A         ;SAVE DATA
00290          BIT 7,A        ;CHECK ALL SHIFT BIT
00300          JR Z,NASHFT    ;NOT ALL SHIFT
00310          LD A,1         ;YES-SHIFT BIT DATA
00320          LD L,80H       ;SHIFT ADDRESS
00330          LD (HL),A      ;SET SHIFT BIT
00340          RES 7,C        ;CLEAR ALL SHIFT BIT
00350          LD A,C         ;GET DATA
00360 NASHFT   CP LFBRKT      ;UPPER LIMIT CHARACTER
00370          JR NC,VALIDQ   ;ONLY ONE VALID ABOVE THIS
00380          CP ATSN        ;CHECK IF ALPHABETIC
00390          JR C,NOALPH
00400          RRCA           ;/2 - YES,GENERATE
00410          RRCA           ;/4 - ADDRESS BIT
00420          RRCA           ;/8
00430          AND 03         ;MASK ALL BUT TWO BITS
00440          INC A          ;ADJUST COUNT TRUE
00450          LD B,A         ;SET UP LOOP COUNT
00460          XOR A          ;CLEAR A
00470          SCF            ;CARRY TO BE SHIFTED IN
00480 GENADR   RLA            ;GENERATE ADDRESS BIT
00490          DJNZ GENADR
00500          LD L,A         ;SAVE ADDRESS
00510 DATA     LD A,C         ;RESTORE ASCII DATA
00520          AND 07         ;MASK ALL BUT THREE BITS
00530          LD B,A         ;MOVE TO COUNTER
00540 DATA1    XOR A          ;CLEAR A
00550          SCF            ;CARRY TO BE SHIFTED IN
00560          INC B          ;MAKE COUNT TRUE
00570 GENDAT   RLA            ;GENERATE DATA BIT
00580          DJNZ GENDAT
00590          LD (HL),A      ;SET BIT IN MEMORY
00600          LD L,0FFH      ; KEY PRESSED BYTE
00610          LD (HL),A      ;SET KEY PRESSED BIT
00620 NVALID   POP BC         ;RESTORE REGISTER
00630          JP KBINT1      ;FINISH BY DOING NORMAL
00640                         ;KEYBOARD INTERUPT ROUTINE
00650 NOALPH   CP '!'         ;IS IT CONTROL?
00660          JR C,CNTRL     ;YES
00670          BIT 3,A        ;NUMERIC OR SPECIAL?
00680          JR NZ,NONUM
00690          BIT 4,A        ;CHECK IF SHIFT
00700          LD B,10H       ;SAVE ADDRESS BIT
00710          JR NC,NOSHFT
00720 SHFT     LD L,80H       ;SHIFT ADDERSS
00730          LD A,1         ;SHIFT BIT
00750 NOSHFT   LD L,B         ;SET ADDRESS BIT
00760          JR DATA
00770 NONUM    LD B,20H       ;SAVE ADDRESS BIT
00780          AND 14H        ;CHECK IF SHIFT
00790          JR Z,SHFT
00800          XOR 14H        ;CHECK IF SHIFT
00810          JR Z,SHFT
00820          JR NOSHFT
00830 VALIDQ   CP RUBOUT      ;THIS IS BACK ARROW KEY
00840          JR NZ,NVALID
00850 CNTRL    LD HL,CTRLTB   ;TABLE ADDRESS
00860          LD BC,8        ;LOOP COUNT
00870          CPIR           ;SEARCH TABLE FOR MATCH
00880          JR NZ,NVALID   ;NOT FOUND
00890          LD HL,3840H    ;CONTROL BIT ADDRESS
00900          LD B,C         ;LOAD LOOP COUNT
00910          JR DATA1       ;COMPUTE BIT AND FINISH
00920 CTRLTB   DEFB SPACE
00930          DEFB RTAROW
00940          DEFB RUBOUT
00950          DEFB LF
00960          DEFB UPAROW
00970          DEFB ESC
00980          DEFB ENQ
00990          DEFB CR
01000 INTMSK   EQU 13H
01010 KBRD     EQU 4
01020 LFBRKT   EQU 5BH
01030 RUBOUT   EQU 7FH
01040 SPACE    EQU 20H
01050 RTAROW   EQU 9
01060 LF       EQU 1B
01070 UPAROW   EQU 0BH
01080 ESC      EQU 1BH
01090 ENQ      EQU 5
01100 CR       EQU 0DH
01110 ATSN     EQU 40H
01115 ;-----------------------
01120 ;THIS IS THE NORMAL KEYBOARD INTERUPT SERVICE ROUTINE
01130          ORG 0FC9CH
01140 KBDINT   PUSH HL
01150          PUSH AF
01160 KBINT1   LD HL,KEBDAT   ;SAVE ADDRESS FOR DATA
01170          IN A,(KBRD)    ;GET DATA
01180          LD (HL),A      ;SAVE IT
01190          CP CTRLZ       ;TO RETURN TO MONITOR
01200          LD A,10H       ;ENABLE ALL INTERUPTS
01210          OUT (INTMSK),A
01220          JR Z,TOMON     ;IT WAS CONTROL Z
01230          DEC HL         ;POINT TO STATUS WORD
01240          SET B,(HL)     ;SET KEBD FLAG
01250          POP AF
01260          POP HL
01270          EI             ;ENABLE INTEPUPTS
01280          RET            ;RETURN FROM INTERUPT
01290 TOMON    POP AF         ;RESTORE REGISTERS
01300          POP HL         ; FOR SAVE ROUTINE
01310          JP RGSAVE      ;SAVE REGISTERS AND GO TO MONITOR
01320 KEBDAT   EQU 0F03AH
01330 CTRLZ    EQU 1AH
01340 RGSAVE   EQU 0F8C9H
01350          END
```

Listing 1. TRS-80 Keyboard Simulator program converts the ASCII data from my keyboard to the memory-mapped bits expected by the Level II BASIC ROM. Program is simpler than it might have been due to the logical placement of the keys in the keyboard matrix (see Fig. 1).

EPROM, and I ordered the Level II ROMs.

Getting Ready

While waiting for the ROMs to arrive, I wrote a couple of programs to simulate the TRS-80 hardware, and I made a couple of hardware modifications to my computer in those areas that could not be readily done with software. The first program, in Listing 1, simulated the TRS-80 memory-mapped keyboard. This program is an interrupt driver that must be used as such. The program exits by jumping to my normal keyboard interrupt routine.

As you can see, the normal routine checks for a control-Z character and jumps to the monitor if it detects one. This is an invaluable feature of my monitor. This allows me to always jump back to the monitor if for some reason the executing program hangs up (except if it disables interrupts or destroys the monitor RAM area).

If you don't have an interrupt-driven keyboard, you can't use the program in Listing 1, but don't worry, you can still put Level II on your computer. It is highly desirable that you have some method of interrupting the computer, saving the registers, etc., and jumping back to your monitor. It is also necessary that you use interrupt mode 2 on the Z-80, since the other interrupt locations are used by Level II BASIC.

If you use Listing 1 with most keyboards, you will not be able to enter the same character twice in a row! The reason for this is because when the program sets the bits in memory to simulate the TRS-80 keyboard, it never resets the bits until the

```
;BASIC INITILIZATION ROUTINES
;RICHARD J. USCHOLD
PCG      EQU 1CH
SPACE    EQU 0F62FH
CHIN     EQU 0F859H
JPIGRT   EQU 0F5CFH
VIDVEC   EQU 401EH
INITVT   EQU 0FD00H
TVT      EQU 14H
PRTVEC   EQU 4026H
LINEPP   EQU 4028H
KBDVEC   EQU 4016H
JMP4     EQU 0FC59H
KBDST    EQU 0F039H
RUBOUT   EQU 7FH
BS       EQU 8
ENQ      EQU 5
CHRCNT   EQU 402AH
TYPOUT   EQU 0F368H
OK       EQU 0F84AH
L2VID    EQU 33H
TRHDLR   EQU 4012H
INTMSK   EQU 19H
BOOT     EQU 69FH
SVPC     EQU 0F051H
DELAY    EQU 60H
CRET     EQU 0DH
TRSCRS   EQU 0FFH
VIDJMP   EQU 0F062H
UPRROW   EQU 5BH
NMIVEC   EQU 66H
;GENERATE TRS-80 GRAPHICS
         ORG 0F5E9H
BASIC    IN A,(PCG+2)  ;DISABLE WRITE PROTECT ON
;PROGRAMMABLE CHARACTER GENERATOR
         LD HL,33FFH   ;LAST PRG CHR ADDRESS
         LD C,0FFH     ;DATA FOR LAST CHARACTER
         LD D,40H      ;64 CHARACTER COUNT
MAINLP   LD E,4        ;4 DOT ROWS PER CHAR COUNT
CHARLP   LD B,2        ;SHIFT LOOP COUNT
SHFTLP   RLC C         ;GET DATA TO CARRY
         RRA           ;ROTATE CARRY TO ACC
         SRA A         ;COPY BIT TO FOUR PLACES
         SRA A
         SRA A
         DJNZ SHFTLP , ;DO NEXT FOUR BITS
         LD B,4        ;4 LINES PER DOT ROW COUNT
DOTLOP   LD (HL),A     ;LOAD DATA TO PRG CHR
         DEC HL        ;BUMP TO NEXT ADDRESS
         DJNZ DOTLOP   ;DO 4 LINES
         DEC E         ;CHARLOOP COUNTER
         JR NZ,CHARLP
         LD A,C        ;GET DATA FOR NEXT ROW
         SUB 41H       ;GENERATE NEXT DOT ROW
         LD C,A        ;SAVE NEXT DOT ROW
         DEC D         ;MAIN LOOP COUNTER
         JR NZ,MAINLP
         IN A,(PCG+3)  ;PROTECT MEMORY
;BASIC COMMAND DECODE - THE NEXT TWO LINES ARE PARTICULAR TO MY MONITOR
         CALL SPACE    ;TYPES A SPACE
         CALL CHIN     ;GET A CHARACTER FROM KEYBOARD AND ECHO IT
         CP 'C'        ;FOR CONTINUE
         JR Z,RETBAS ;GO BACK TO BASIC
         CP 'I'        ;FOR INITIALIZE
         JP Z,0001     ;INITIALIZE BASIC
         CP 'R'        ;FOR RESET
         JR NZ,JPIGRT  ;ILLEGAL CHARACTER
;THIS ROUTINE PRINTS ILLEGAL CHARACTER MESSAGE AND RETURNS TO THE MONITOR FOR THE NEXT COMMAND
         JP NMIVEC     ;TRS-80 RESET SWITCH
         NOP
         NOP
         NOP
         NOP
RETBAS   LD HL,VIDPCH ;INIT VIDIO PATCH
         LD (VIDVEC),HL ;CHANGE TRS VECTOR
         CALL INITVT   ;THIS SETS UP MY TVT AND
;CLEARS THE SCREEN. THIS IS PARTICULAR TO MY TVT AS IS THE NEXT LINE
         LD A,0CEH     ;NO SCROLL, CURSER OFF
         OUT (TVT+2),A
;THIS NEXT SECTION SETS UP A JUMP ADDRESS SO I CAN SWITCH BETWEEN THE NORMAL SPACE
;COMPRESSION CODES OR 64 MORE PROGRAMMABLE CHARACTERS
         LD HL,VIDJMP  ;JUMP TO 04A6 DOES SPACE
         LD (HL),0C3H  ;COMPRESSION CODES. JUMP
         INC HL        ;TO 047D DOES PROGRAMMABLE
         LD (HL),0A6H  ;CHARACTERS. FROM BASIC,
         INC HL        ;POKE -3988,125 FOR PRG
         LD (HL),04H   ;CHRS, POKE -3988,166
                       ;FOR TABS
         LD HL,TRSPRT  ;PRINTER DRIVER
         LD (PRTVEC),HL
         LD HL,KBDSUB    ;KEYBOARD SUBTITUTE DRIVER
         LD (KBDVEC),HL  ;CHANGE TRS VECTOR
         LD A,57
         LD (LINEPP),A ;PRINTER LINES PER PAGE
         NOP
         JP JMP4           ;THIS IS THE SECTION IN
;MY MONITOR WHICH RESTORES THE REGISTERS AND RETURNS TO THE MAIN
;PROGRAM - AS FROM A CONTROL Z INTERUPT.
```

Listing 2. The first part of this program generates the bit patterns necessary to program my programmable character generator so it simulates the TRS-80 graphics. The second part sets up my computer so it is compatible with the Level II BASIC ROM.

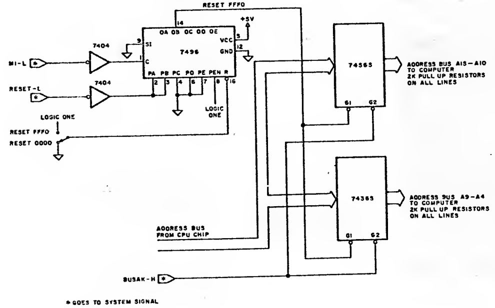


Fig. 2. Alternate reset vector circuit. Address FFF0 must be in PROM and contain a three-byte jump instruction to the start of the monitor.

next key is hit. If the next key is the same as the last one, the same bits will be set and the ROM will think you have not released the key yet!

There are several solutions to this problem. I modified my keyboard so it gives a second data strobe when a key is released. This will strobe in a null, and the program will clear the memory when the key is released. Another solution is to hit any key on the keyboard that is not encoded by the program. This will clear the memory and leave it that way. This is only necessary if you wish to hit the same character twice in a row.

Actually, I don't really recommend you use this program. I am only describing it since it is the way I started this project. Later,

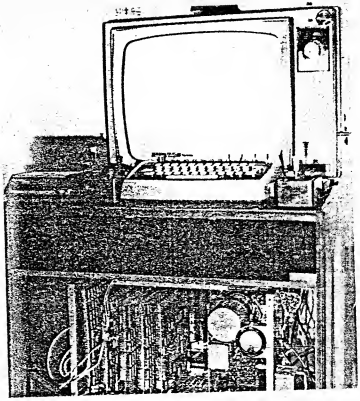


Photo 2. My completely home-brew system. The first board contains the TVT and programmable character generator. Board 2 has my front panel logic, the interrupt logic, EPROM programmer, two serial ports and the cassette interface, which supports Kansas City Standard, Tarbell, PE2400 Radio Shack Level II and CUTS with a slight mod. The third board contains the Z-80 CPU chip, 10K of static RAM, 3K EPROM, the clock switch and "No Memory" interrupt circuit. Board 4 is a 12K static RAM board. The fifth board contains a joystick interface, Level II ROMs, alternate reset circuit, floppy disk interface, real-time clock and sockets for 32K of dynamic RAM.

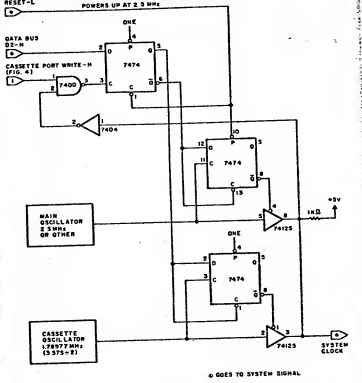


Fig. 3. Clock switch circuit automatically switches the clock from the normal frequency (2.5 MHz on my system) to 1.79 MHz when I/O port FF is written with bit 2 set. It switches back when port FF bit 2 is reset. This bit is the TRS-80 cassette motor control bit.

I'll tell you what you should use and what I am now using.

Another noteworthy feature about this program is the shift. The TRS-80 keyboard program generates lowercase characters if the shift key is pushed with a regular key. It also generates special control characters when the shift is pushed with the arrow keys.

I handled this by using the eighth bit as the shift bit. My keyboard has an extra key that sets the eighth bit when pushed. Most keyboards don't have this.

The second program I wrote while waiting for the ROMs is an Initialization of my system so that the ROMs will think they are hooked up to a TRS-80. Listing 2 essentially is the program, although it is a little bit different. I changed it slightly after I got the ROMs and learned a few things I didn't originally know.

The first part of the program initializes my programmable character generator to simulate the TRS-80 graphics characters. The programmable character generator is essentially the same as the one described in *Byte* magazine (May and June 1978). There are 128 programmable characters that can be printed by sending the codes 80H–FFH to the video driver or directly loading these codes in

Photo 1. Level II kit. ROMs have been removed from the circuit board. (Photos by Michael Tabellion).

TVT memory area. The 3-80 has 64 graphics characters having codes 80H–BFH. These corresponding characters are generated by the program.

The next section, command decode, checks for one of three options: Initialize, continue or reset. The initialize section jumps to the ROM so it can initialize the Level II RAM area as it requires. The reset jumps to the ROM, where the reset button on the TRS-80 would send it. This is used when the Level II hangs up and you do not wish to destroy the BASIC program in memory.

On my system, I type a control-Z to get back to the monitor and then BR. B is the BASIC command in my monitor that jumps to the program I am now describing. R is the reset option. The continue option initializes a few more things, which I'll describe later, restores the registers and continues where it was interrupted (usually by a control-Z). I frequently use this to save BASIC programs with my 2400 baud cassette interface rather than use Level II's 500 baud cassette interface.

I made several hardware mods to accommodate the Level II ROMs. The simplest was to move my RAM, EPROM and TVT RAM to the proper locations. The TRS-80 hardware manual has a memory map, so this was no real problem. The other two mods were a bit more involved. Both of these mods are for the cassette interface.

The first one (Fig. 3) changes the clock speed during the cassette operation. Normally my computer runs at its rated speed of 2.5 MHz; during a cassette operation, the speed is reduced to 1.7898 MHz. This is about one percent higher than the TRS-80 clock and is more than close enough when you consider the tolerance of the cassette machine.

The required clock rate is one-eighth the rate of my TVT clock, so I didn't require another oscillator. The required clock is also one-half the color burst frequency. There are inexpensive crystals available that you can use; 3.579 MHz color burst crystals cost less than $2.

The other changes are more directly related to the cassette interface itself (Fig. 4). The output circuit is little more than a couple of latches and a few resistors. I also added some Tri-state buffers so I could use the same cable as my 2400 baud interface. The first input circuit I tried is simpler than what the TRS-80 has, with three fewer op amps and many fewer resistors and capacitors. The idea was to change the input circuit I've been using with my 2400 baud interface as little as possible.

Well, I was finally ready for the ROMs, which would not arrive for over a month.

The ROMs Arrive

After calling the company twice, asking where my order was, I finally received the ROMs, which came on a small circuit board with a 24-pin jumper cable cable. No instructions came with the kit; however, the handbook shows a schematic of the circuit board (Fig. 5). There are also other items, including an unprogrammed DIP header and a resistor, in the kit (see Photo 1). The DIP header alters the ROM decode in the TRS-80; I'm not sure what the resistor is used for. Anyway, I didn't use either of these.

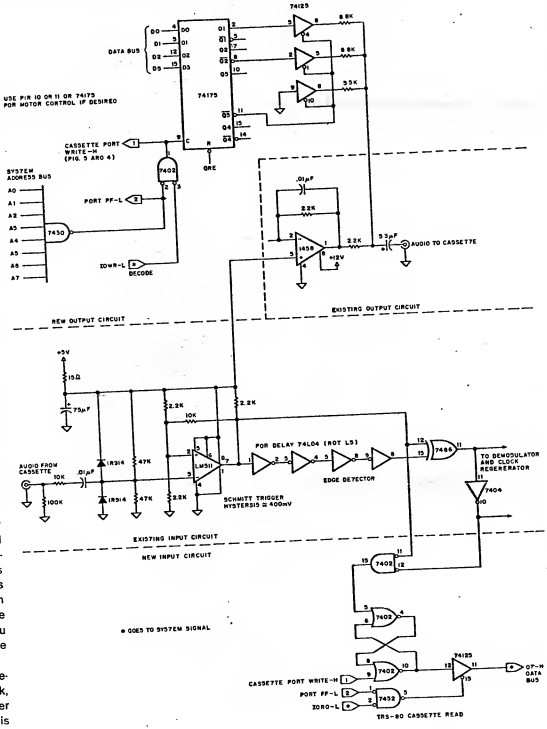


Fig. 4. Cassette output circuit similar to the TRS-80. I added the Tri-state buffers and changed the resistor values a bit so I could wire it directly to my existing output circuit. You can use bit 2 for cassette motor control if you wish.

Also included are three prerecorded cassettes with some very brief instructions on how to use them. One cassette contains Blackjack and Backgammon. The other two cassettes are for conversion of Level I programs and data to Level II format. I haven't had a need for these two yet, though I have used the games a few times. Finally, there is the "Level II Reference Manual," along with errata sheets, containing useful information.

The small circuit board didn't seem to fit anywhere in my system, so I wired up three sockets and just removed the ROMs. A friend had given me a poor copy of a copy containing a hex dump of the ROMs and partial disassembly of the initialization portion of the program. The first thing I did was to check the first few bytes in each ROM. They matched! Next, I ran off a hex dump of my own so I could read it without straining my eyes.

There was one more thing I wanted to do before I actually tried to execute the program contained in the ROMs. From all the information I had acquired, I knew that the TRS-80 used interrupts only when it had the expansion interface connected. Also, it only used interrupt mode 1 on the Z-80 chip. Since my system would only work if I used interrupt mode 2, I searched the ROMs for any instructions that affected the interrupts. There were two: a disable interrupts at 0000H and an enable interrupts at 06E4H.

The enable interrupt instruction is actually the interrupt service routine, which is moved to RAM during the initialization. The routine merely enables interrupts and returns. This is modified when interrupts are needed. What all this boils down to is that I shouldn't have any problems with my interrupt-driven keyboard as long as I start the ROM at 0001H.

The Big Moment

So, I tried it. The screen cleared, and a short message appeared in the upper-left corner. It said, "ξςξπτ√ υx→ς?__." My computer was talking to me in Greek! There was obviously some incompatibility between the TRS-80 video driver and my TVT. The Level II manual tells me that the computer is supposed to say, "MEMORY SIZE?__." Anyway, I responded with a "32000," which appeared on the screen just as I typed it.

Hmmmm, my keyboard kludge was working alright and the numerals printed correctly, but the alphabet was in Greek! I hit the carriage return. Nothing happened for a moment, then another couple lines of Greek appeared.

You may be wondering where the Greek was coming from. Well, that is an easy one. The character generator ROM I bought for my TVT has Greek characters and some special math symbols where the control

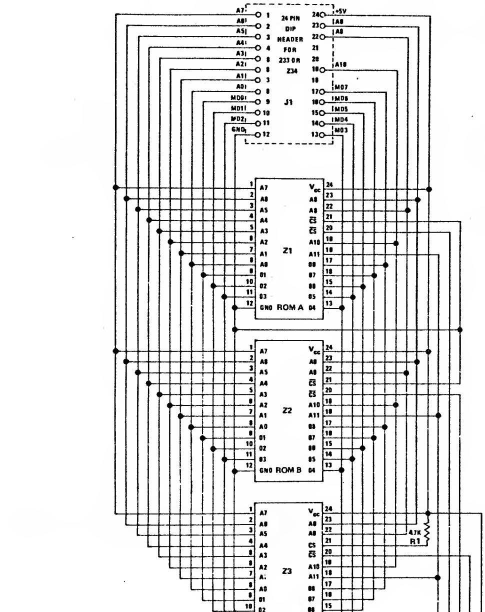
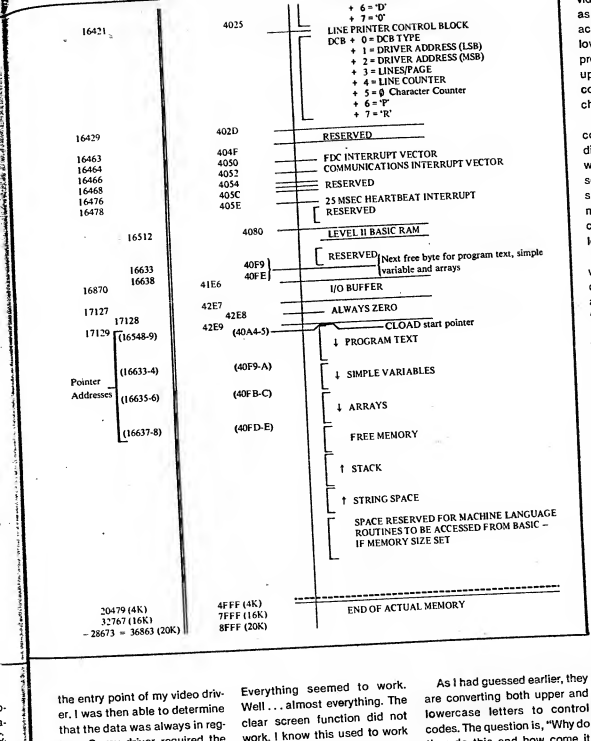


Fig. 5. Level II BASIC schematic. (Reprinted from the "TRS-80 Technical Reference Handbook," courtesy Radio Shack.)



as a numeral or a special character. So they had to convert lowercase to uppercase. It was probably simpler to convert both upper and lowercase letters to control codes than to just change lowercase to uppercase.

Anyway, as far as they were concerned, that particular bit didn't really matter because it was not even in the RAM! Personally, I think they should have spent the extra buck on one more memory chip, then they could have had both upper and lowercase on the computer.

The final solution I came up with was to duplicate the first dozen instructions of their driver and then skip over the section that screws up the characters and jump back to their driver. The total patch is about 40 bytes.

Listing 3 shows that I have included two more small patches to the driver. The first changes the up-arrow code from 5B (which prints a left bracket([)) to 1C, so it prints an up arrow on my TVT. Radio Shack mentions in the Level II manual that some TRS-80s may print the up-arrow as a left bracket. The second allows me to bypass the space-compression codes and print 64 more of my programmable characters instead. This is accomplished by poking one byte in a memory location.

The Cassette Interface

Having gotten the video driver working made me feel very confident. I was now ready to attack the cassette interface. I placed the Blackjack tape supplied with the Level II kit in the recorder (a Radio Shack CTR-40) and typed CLOAD. I have a small tape controller box, which enables me to hear the data while the computer is reading it. This is convenient because you can tell the difference in the sound of the actual data and the leader tone on the tape.

I turned on the recorder and hit the return key. One nice thing about the TRS-80 cassette driver is that two asterisks flash in the upper-right corner of the screen when the computer is reading data. The asterisks first appear

the entry point of my video driver, I was then able to determine that the data was always in register C; my driver required the data in register A. I patched this in and tried again.

Now I was getting data, but everything was on the same line! There were only carriage returns and no line feeds! It seems the TRS-80 video driver automatically generates a line feed when it gets a carriage return. As it turns out, my video driver generates a carriage return if it gets a line feed! So I checked for carriage returns and converted them to the line feeds and tried again.

Now that was much better! Everything seemed to work. Well . . . almost everything. The clear screen function did not work. I know this used to work when everything was in Greek. Referring again to the Level II manual, I noticed they have a table that describes all of the control codes that are implemented (Table 1).

I had two choices: modify my video driver to handle all of the control codes or try to see if I could patch their video driver so it would work. Half out of curiosity as to what they were doing and why it worked (on a TRS-80) and half because I didn't really feel like rewriting my driver, I disassembled their driver.

As I had guessed earlier, they are converting both upper and lowercase letters to control codes. The question is, "Why do they do this and how come it works?" The answer is in the hardware manual. It seems they thought it would be less expensive to use only seven bits of information in the video RAM instead of eight. They use one bit to select graphics characters or regular characters. That leaves six bits for the ASCII code.

But the ASCII code is a seven-bit code; how can that work? They cheat a little. The seventh ASCII bit is generated with a NOR gate from two other bits. This means that if they sent an

characters would normally be. Most video drivers don't actually send control characters to the video RAM; rather, they decode them and take the appropriate action. For some strange reason, the TRS-80 video driver was changing the normal alphabetic codes to control codes before sending them to the video RAM.

The First Program (in Greek)

I know that some people think that programming computers is like talking in Greek, but this is ridiculous! The Level II manual has a short program in the back which will display all of the graphics characters. I typed the program into my computer . . . in Greek! I changed it slightly, so it would print all characters not including the control codes. After I finished typing it, I listed it. Since I can't read Greek, I couldn't tell if I had it right or not, but at least the list command worked.

Next I typed "τχο;" that's RUN, for those of you who don't know Greek. Characters flashed by on the screen, and scrolled off before I could read them. I ran it again, but I halted the computer before everything disappeared. The special characters and numerals looked good. Then there were two sets of Greek characters where the uppercase and lowercase should be. Next came the graphics characters, which looked all right.

Fig. 6. Level II TRS-80 memory map. (Reprinted from "Level II BASIC Reference Manual," courtesy Radio Shack.) I have added a few addresses I have discovered.

D/LEVEL II TRS-80 MEMORY MAP

ADDRESS DECIMAL	HEXIDECIMAL	
0	0000	LEVEL II BASIC ROM
12288	3000	RESERVED
14302	37DE	COMMUNICATION STATUS ADDRESS
14303	37DF	COMMUNICATION DATA ADDRESS
14304-7	37E0-3	INTERRUPT LATCH ADDRESS
14304-7	37E0-3	DISK DRIVE SELECT LATCH ADDRESS
14308-11	37E4-7	CASSETTE SELECT LATCH ADDRESS
14312-5	37E8-B	LINE PRINTER ADDRESS
1436-9	37EC-F	FLOPPY DISK CONTROLLER ADDRESS
14336	3800	TRS-80 KEYBOARD
15360	3C00	MEMORY TRS-80 CRT
16383	3FFF	VIDEO MEMORY
16384	4000	LEVEL II BASIC FIXED RAM
16402	4012	VECTORS (RST'S 1 THROUGH 7)
16405	4015	KEYBOARD DEVICE CONTROL BLOCK
		DCB + 0 = DCB TYPE + 1 = DRIVER ADDRESS + 2 = DRIVER ADDRESS + 3 = Ø + 4 = Ø + 5 = Ø + 6 = 'K' + 7 = 'I'
16413	401D	VIDEO DISPLAY CONTROL BLOCK DCB + 0 = DCB TYPE + 1 = DRIVER ADDRESS (LSB) + 2 = DRIVER ADDRESS (MSB) + 3 = CURSOR POS N (LSB) + 4 = CURSOR POS N (MSB) + 5 = CURSOR CHARACTER

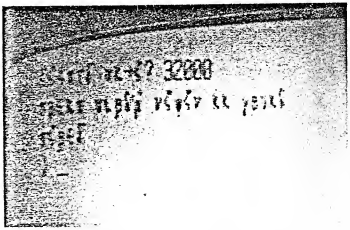


Photo 3. Initial run of Level II BASIC. Translation:

```
MEMORY SIZE? 32000
RADIO SHACK LEVEL II BASIC
READY
>_
```

Finally, there were all of those spaces, as everything scrolled off the screen. The Level II manual has a good explanation for the scrolling phenomenon. The codes, C0H to FFH, are space-compression codes for 0-63 spaces. So, by printing all of those codes, I had printed about 2000 spaces to the screen. I changed the program so it did not print the space-compression codes and ran it again. This time it didn't scroll off the screen.

Video Driver Patch

I remembered something I had seen in the Level II manual, which showed a memory map, which had a detailed description of some of the RAM locations used by the Level II BASIC. I was interested in a short section of 25 RAM locations containing three device control blocks. There were control blocks for the keyboard, the video display and the line printer. As you can see from Fig. 6, among other things, each block contains a driver address.

Now I figured all I had to do was to change the driver address to my own video driver, and I would be in business. I tried it. Nothing! I guessed that they used a different register to transfer the data byte. With this in mind, I set up a breakpoint at

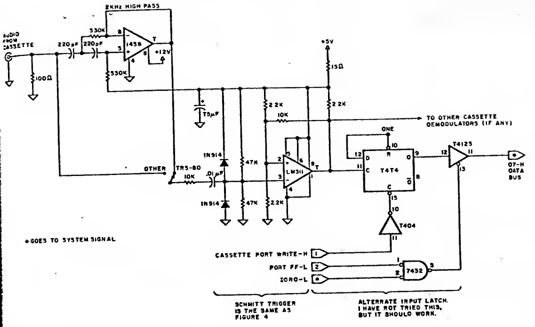


Fig. 7. Cassette input circuit I am now using. The 2 kHz high-pass filter is switched in to read Radio Shack tapes. The Schmitt trigger section is the same as in Fig. 4. The input latch is simpler than that shown in Fig. 4.

computer doesn't immediately respond with READY; if READY occurs before the data ends; or if the asterisks do not flash. If the asterisks flash slowly or erratically, the load may be bad. This clue takes some getting used to since the flash rate is not the same for all programs. You have to get a feel for how the asterisks normally flash.

If any of these symptoms occur, you will have to reload the program. Several of these problems cause the computer to hang up. A reset must then be issued to get back to BASIC.

During the next few weeks, I tried all of my 100 programs. I found that some of the tapes read fairly well, while others were very poor. These tapes have the same programs recorded on both sides as a backup. I found that I couldn't read some programs at all; I could read only one side correctly on some tapes; and I could read both copies on others. I tried reading some of these programs on a real TRS-80, and some that I couldn't read worked.

Since my input circuit was considerably simpler than the one they use, I breadboarded their circuit and tried it. It worked much better. The volume setting was less critical, but it was still more sensitive than I would have liked. With some experimenting, I found that I only needed the high-pass filter section of their interface. Since the TRS-80 tape format was so much improved with the filter, I tried it on my 2400 baud interface. It bombed. My interface became totally useless with the active filter.

The reason I attribute to this seeming inconsistency is that the Radio Shack recording method is an amplitude modulation scheme, while my interface is a phase modulation scheme. The active filter adds too much phase distortion for my interface to work properly.

The final circuit I implemented for my cassette interface is shown in Fig. 7. The switch is to select Radio Shack or other recording methods. I'm not really sure if my circuit is more or less reliable than Radio Shack's, but my circuit seems adequate. Most of the tapes read through with two or fewer volume adjustments. Some don't need any adjustments. I don't use my Radio Shack interface to save programs anyway, since my 2400 baud interface is nearly five times faster.

One feature of the Radio Shack cassette interface I haven't built is the motor control circuit. I've been using my cassette interface for a year and a half, and I don't think a motor control is necessary. I do use the motor control signal to change the clock frequency and to enable the output circuit though. This works very well.

Keyboard and Printer Patches

I decided to get rid of that keyboard kludge I was using. I wrote the short driver in Listing 4. This program simply checks the keyboard status bit and either returns a null if it is not set or returns the character. It also checks for and changes two characters that were different on my keyboard than what the

```
;VIDIO DRIVER PATCH - PRINTS UPPER AND LOWER CASE
VIDPCH  LD L,(IX+3)   ;GET CURSOR POINTER
        LD H,(IX+4)   ;GET CURSOR POINTER
        JP C,049AH    ;I'M NOT SURE WHAT THIS IS
        LD A,(IX+5)   ;GET CURSOR CHARACTER
        OR A
        JR Z,PATCH1
        LD (HL),A
PATCH1  LD A,C        ;GET CHARACTER
;THE FOLLOWING FEW LINES ADJUST THE UP ARROW CODE FROM THE
,TRS-80 CODE TO THE EQUIVALENT CODE ON THE CHARACTER GENERATOR I
;HAVE, WHICH IS MCM6571A
        CP UPARROW    ;THIS IS THE UP ARROW CODE
        JR NZ,PATCH2  ;IS NOT UP ARROW
        INC C         ;YES ADJUST
        JP 0467H      ;DON'T BYPASS UPPER,LOWER ADJ
PATCH2  CP ' '        ,CONTROL?
        JP C,0506H    ;YES, DO IT
        CP 80H        ;GRAPHICS?
        JP NC,VIDJMP  ;YES, DO IT
        JP 047DH      ;NO, ALL OTHER
```

Listing 3. Patch to the TRS-80 video driver eliminates the section that converts lowercase and uppercase character codes to control character codes. This permits both upper and lowercase to be printed.

TRS-80 Key	ASCII	Hex	Normal Keyboard
BREAK	SOH	01	CTRL A
←	BKSP	08	CTRL H
→	HT	09	CTRL I
↓	LF	0A	CTRL J
↑	[	5B	[
ENTER	CR	0D	RETURN
SHIFT ←	CAN	18	CTRL X
SHIFT →	EM	19	CTRL Y
SHIFT ↓	SUB	1A	CTRL Z
SHIFT ↑	ESC	1B	ESCAPE
CLEAR	VS	1F	

Table 2. Control codes generated by the keyboard driver on the Level II BASIC ROMs. Your keyboard must generate these characters also.

when the actual data on the tape starts, just after the leader tone ends. They then flash as each line of program is read.

Somewhat to my surprise, the asterisks appeared and began flashing as soon as the leader tone ended. As soon as the data ended, the computer typed READY. I typed RUN. The program started executing! It asked me several questions, including my name.

After my second or third response, the program bombed. Oh well, I knew it was too good to be true. I adjusted the volume on the recorder and tried again. After several repeats of the above, the program actually ran all the way through. Ah, success at last. Next, I tried making a tape. I had to adjust the volume several times to get it to read back correctly, but this also worked.

The volume setting on the tape recorder is critical. I usually have to adjust it several times before I can get a program to load correctly.

I bought the Library 100 from The Bottom Shelf, Inc. This is a five-cassette package of 100 assorted programs for the TRS-80. I have to adjust the volume several times even to read programs on the same cassette. According to the hardware manual, the data on the cassette is saved with a checksum. This is useful for detecting load errors.

The only problem is that the Level II cassette loader program does not check the checksum and tell you when a bad load has occurred. My own cassette loader does this, and while I don't have frequent errors, it sure is nice to know that the load is bad before you try to execute the program.

I have discovered several ways to help determine if a load is good or not. The load will be bad if the asterisks appear before or after the point on the tape where the data actually starts; if the data stops and the

Code	Hex	Function
0-7	00-07	None
8	08	Backspaces and erases current character
9	09	None
10-13	0A-0D	Carriage returns
14	0E	Turns on cursor
15	0F	Turns off cursor
16-22	10-16	None
23	17	Converts to 32 character mode
24	18	Backspace → Cursor
25	19	Advance ← Cursor
26	1A	Downward ↑ linefeed
27	1B	Upward ↓ linefeed
28	1C	Home, return cursor to display position(0,0)
29	1D	Move cursor to beginning of line
30	1E	Erases to the end of the line
31	1F	Clear to the end of the frame

Table 1. Control codes decoded by the video driver on the Level II BASIC ROMs. (Reprinted from "Level II BASIC Reference Manual," courtesy Radio Shack.) I have added hex codes.

gram's attention is with an interrupt. If you have an interrupt-driven keyboard, you could use a program such as Listing 1 to simulate the TRS-80 memory-mapped keyboard, as I did at first. Otherwise, you need some other means of interrupting the computer. This could be as simple as a switch to the interrupt line on the Z-80. The interrupt service routine could simply change the keyboard driver address and then return to the Level II program.

There are only two situations where you could get by without any interrupts. If you actually connect your keyboard the same way as Radio Shack did, you wouldn't need interrupts. If you already have a keyboard connected some other way, rewiring it is probably undesirable. Or, if you have a hardware front panel, you could interrupt the computer that way and change the keyboard driver address. While that is not really very difficult, it is kind of a bother to flip all those switches. My system includes a front panel, and I didn't want to do it that way.

The method I used to interrupt the computer is a bit unusual for a microprocessor. I have a circuit in my computer that generates an interrupt if the computer attempts to read a memory address at which there is no memory installed (see Fig. 8). This interrupt saves all the registers, prints a "No Memory" message and jumps to my monitor. When the ROM tries to read the keyboard, this interrupt is generated because I don't have any memory there. From here I simply type BC, a monitor command that stands for BASIC Continue.

Listing 2 is the program. Its function is very simple—it merely sets up the new driver addresses for the keyboard, TVT and the printer. Then it restores all the registers and returns to where it was interrupted.

TVT Specifics

If your TVT is a memory-mapped device with 16 lines of 64 characters, you should have no problems getting it to work with Level II BASIC. You will have to change its address to 3C00-3FFF. If you don't have a programmable character generator, you will have to modify the TVT to implement the TRS-80 graphics. The modification should consist of only three ICs as shown in Fig. 9.

Fig. 10 shows the graphics-character format. As you can see, each character cell is divided into six blocks. Each block is controlled by one bit in the video memory. The most significant bit determines if a particular character is a graphics character or a regular character. The multiplexers simply steer the bits to the appropriate positions.

This circuit will work for TVTs, which have a character cell con-

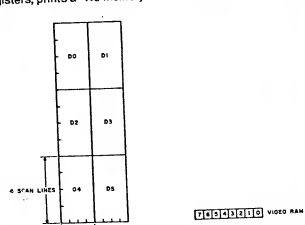


Fig. 10. Scale drawing of one character cell shows that each graphics dot is approximately twice as tall as it is wide. The video RAM bits that control each graphics dot are also shown. This format matches the circuit in Fig. 9.

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```
01290 ;TRS-80 SUBSTITUTE KEYBOARD DRIVER
01300 KBSTAT LD HL,KBSUBT ;KEYBOARD STATUS ADDRESS
01310        BIT 0,(HL)
01320        JR NZ,KBSB1  ;YES, ITS READY
01330        XOR A        ;NOT READY
01340        RET          ;RETURN WITH A NULL
01350 KBSB1  RES 0,(HL)   ;RESET STATUS BIT
01360        INC HL       ;BUMP POINTER TO DATA
01370        LD A,(HL)    ;GET DATA
01380        CP RUBOUT    ;IS IT A RUBOUT?
01390        JR NZ,KBSB2  ;NO
01400        LD A,8S      ;YES, LOAD BACKSPACE
01410        RET          ;AND RETURN
01420 KBSB2  CP ENQ       ;THIS IS FOR CLEAR KEY
01430        RET NZ       ;NOT CLEAR, RETURN
01440        LD A,1FH     ;YES, LOAD CLEAR CODE
01450        RET          ;AND RETURN
01460 ;PRINTER DRIVER PATCH
01470 TKSPRT LD A,C       ;MOVE DATA TO CORRECT REG
01480        LD HL,CHRCNT ;GET POINTER
01490        CP 0DH       ;FROM FEED
01500        JR Z,FORMF   ;INITIALIZE LINE COUNT
01510        CP 0DH       ;CARRIAGE RETURN
01520        JR Z,CR      ;DO CARRIAGE RETURN
01530        LD A,(HL)    ;GET CHAR COUNT
01540        CP 48H       ;=64?
01550        CALL Z,CR    ;INSERT A CR IF =64
01560        LD A,C       ;GET DATA AGAIN
01570 TKSPR1 CALL TYPOUT  ;OUTPUT CHAR TO PRINTER
01580        INC (HL)     ;BUMP CHAR COUNTER
01590        RET          ;DONE
01600 CR     DEC HL       ;POINT TO LINE COUNT
01610        LD A,(HL)    ;GET LINE COUNT
01620        DEC HL       ;POINT TO LINES PER PAGE
01630        INC A        ;BUMP LINE COUNT
01640        CP (HL)      ;AT LIMIT?
01650        INC HL       ;POINT TO LINE COUNT
01660        JR Z,NXTPPG  ;YES, AT LIMIT
01670 CR1    LD (HL),A    ;SAVE NEW LINE COUNT
01680        INC HL       ;POINT TO CHAR COUNT
01690        LD (HL),0FFH ;RESET CHAR COUNT
01700        LD A,0DH     ;GET A CARRIAGE RETURN
01710        JR TKSPR1    ;DO CARRIAGE RETURN
01720 FORMF  DEC HL       ;POINT TO LINE COUNT
01730 NXTPPG CALL OK      ;THIS ROUTINE PRINTS "OK?"
01740 ;AND WAITS FOR A CHARACTER FROM THE KEYBOARD BEFORE CONTINUING
01750 ;THIS ALLOWS ME TO PUT ANOTHER PAGE IN MY PRINTER
01760        XOR A        ;CLEAR A
01770        JR CR1       ;FINISH BY DOING CR
```

Listing 4. Keyboard driver replaces the one on the Level II ROM. It works in conjunction with my normal keyboard interrupt routine in Listing 1. The printer patch replaces the Level II printer driver.

ROM expected.

Actually, there were more characters that didn't quite match, but I reprogrammed my keyboard encoder EPROM to fix those. The reason I didn't fix all of them on the EPROM is because I would have had to change my monitor that used those characters. I figured it was better this way. Table 2 shows the control characters generated by the TRS-80 keyboard.

The printer patch adds a few features that my driver didn't have but are assumed by the Level II ROMs. The major feature is to add extra carriage returns when a line exceeds 64 characters in length. My first printer patch did not do this, and when I listed BASIC programs that had multiple statement lines longer than 64 characters, the extra characters would not print. I also added a lines-per-page counter. When the line count is at the limit, the program waits for me to put another page in my printer.

The routine TYPOUT in Listing 4 converts the ASCII in the special code required by my modified Olivetti Lexikon 82 typewriter. The form-feed check in the program permits resetting the line counter to zero. This should be used before any new listing, so it starts at the top of a new page. From BASIC, the following line will work: LPRINT CHR$(12);.

Specific Hardware Requirements

The single most important hardware requirement for your system is the use of interrupts. The reason for this is the way the keyboard is set up. When the Level II ROM initializes its RAM space, it assumes that you have a memory-mapped keyboard. If you don't have a memory-mapped keyboard and you don't have interrupts either, there is no way you can talk to the Level II program, and the computer will be hung up.

The only way to get the pro-

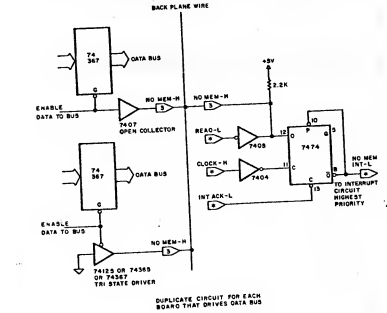

Fig. 8. To use this "No Memory" interrupt circuit, you must add a gate to every board in your system that drives the data bus. This circuit will generate an Interrupt every time a nonexistent memory address or input port is read. This should be the highest priority interrupt in your system.

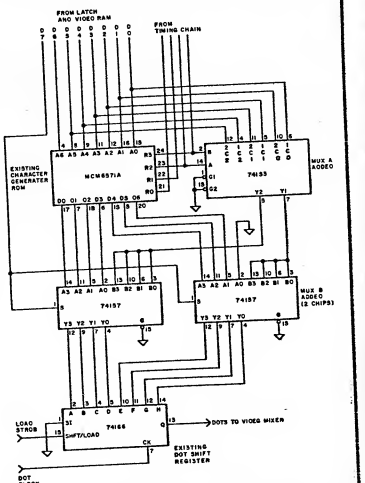

Fig. 9. This simple graphics mod will work for TVTs that use the MCM6571A character generator ROM. If you have a different character generator, the pin numbers will be different, but the circuit will be similar.

sisting of 12 lines of eight dots. If your TVT has 12 lines of six dots, simply tie the two outputs from mux A to each of three inputs on mux B instead of the four shown. If your TVT has a different arrangement of lines and dots, you have several choices.

First, you could stretch or shrink some of the graphics dots so they fill the available lines and dots in the character cell. This may cause some graphics dots to be different sizes than other ones if the total number of lines and dots are not evenly divisible by three and two, respectively.

Second, you could modify your TVT so it has a line count divisible by three and a dot count divisible by two. This is a bit tricky and should be attempted only after you have examined the schematic and understand the timing details of the TVT. The first mod is simpler and doesn't affect the timing, but you should still closely examine the schematic of your TVT before attempting to install the change.

Third, you could forget about the graphics. This is the simplest solution, but since a lot of game programs use the graphics, you may not want to do this. If you never play games, then you don't need the graphics anyway.

I suggest you try the first solution before trying the second. The slightly different size dots will go unnoticed in many applications anyway. My own TVT has a software-selectable character cell size. I can select 13 by 9 or 12 by 8. I normally operate in the 13 by 9 mode and have found it satisfactory in many graphics applications.

If your video terminal is a completely separate unit from your computer, you obviously don't have a memory-mapped device. This means you can't use any part of the TRS-80 video driver. You will have to either write your own or modify the one you are presently using. The most important thing is to have the control characters respond correctly (see Table 1).

There are a few features in Level II BASIC that won't work with this type of setup. The graphics functions, SET, RESET and POINT, won't work, although you could send the graphics characters to the terminal like any other character. The PRINT@ and POS commands won't work either. Everything else should be fine though.

Your First Run

When you first try to run the Level II BASIC, you may have a different sequence of events than I do, depending on just how your hardware is configured. As you recall, my first run produced Greek characters. I no longer get Greek when I initialize the BASIC ROM. The first thing that appears is a "No Memory" message. This occurs when the ROM attempts to read the keyboard memory. I then type BC (BASIC Continue).

As described earlier, this changes some of the RAM locations just initialized by the ROM and returns to Level II BASIC. From here, my system behaves just like a TRS-80.

If you don't have a "No Memory" interrupt on your system, and depending on what your TVT does with control characters, your system could produce Greek characters, some strange graphics characters or absolutely nothing. The next display will depend on what you have in the keyboard memory area. If this memory is all zeros, you will only see one line of whatever characters your system is producing. If the memory is all ones (FF hex) or random data, you should see several lines of these characters continously being written to the TVT and scrolling off the screen.

No matter what you see, you should now hit your interrupt button (control-Z, or whatever) to put you back into monitor. After typing the BASIC Continue command, you should have a blank screen.

The ROM is now waiting for your response to the MEMORY SIZE question, even though you can't see that message. Typing anything should cause it to appear on the screen. Since there may be several unknown characters in the keyboard buffer, you should first delete these with the back-arrow key. When the cursor stops moving back, all characters have been deleted. Now answer the MEMORY SIZE question as you wish. If you hit a carriage return with garbage data, the ROM will ask the MEMORY SIZE question again.

One final note: if, on your system, memory address 37ECH returns anything other than 00 or FFH when read, the ROM may attempt to boot the disk. I'm not sure exactly what will happen, but it will most likely get hung up and do nothing. If you have no memory at that address, you should be OK, since most systems read FFH or 00 to nonexistent memory.

Conclusions

For someone with a Z-80 microcomputer system who is looking for a good BASIC and would prefer to have it on ROM, Radio Shack's Level II ROM add-on kit for their TRS-80 is a good way to go. The price is reasonable—less than many BASICs that only come on cassette. If you consider the additional cost of EPROMs to put another BASIC on ROM, the Level II BASIC is less expensive than any other I know.

That the TRS-80 is the most popular microcomputer today ensures that there will be more directly compatible software than any one person can use. The ROM also contains a floppy disk bootstrap routine. This allows easy addition of one or more mini-floppy disk drives for a more versatile system. Radio Shack's TRSDOS may not be the best, but at only $14.95, it certainly is the most inexpensive disk operating system I have ever seen. ■

References

"TRS-80 Microcomputer Technical Reference Handbook," Radio Shack.
"LEVEL II BASIC Reference Manual," Radio Shack.
"TRSDOS & DISK BASIC Reference Manual," Radio Shack.

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